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Carstens

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[54] **PUMP FOR USE IN A CAPSULE TRANSPORT PIPELINE**

[75] Inventor: **Marion R. Carstens,** Atlanta, Ga.

[73] Assignee: **Georgia Tech Research Institute,** Atlanta, Ga.

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[52] **U.S. Cl.** .... **104/138 R;** 104/88; 105/365

[51] **Int. Cl.** **B61d 13/10**

[58] **Field of Search** 104/88, 138, 155, 365; 243/1, 6; 105/365

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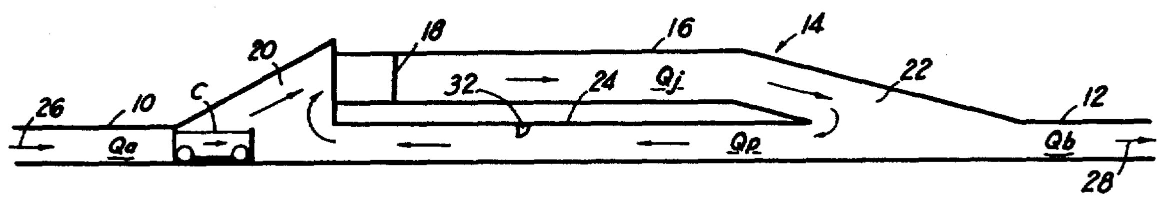
Primary Examiner—M. Henson Wood, Jr.
Assistant Examiner—Richard A. Bertsch
Attorney, Agent, or Firm—Newton, Hopkins & Ormsby

[57] **ABSTRACT**

A closed tube system is used to guide a number of cars around a fixed path and a series of pumping stations are located around the path. Each station is defined by a fluid flow pump section and a car by-pass section which has its opposite ends associated with the inlet and outlet respectively of the pump section. The pump is operated normally so as to create a tendency for reverse flow of air through the by-pass section so that a car in the section adjacent the pump outlet will be held against a pawl-type stop in the car by-pass section by positive pressure.

Four methods of car injection are proposed. The first is to create a forward flow of air in the car by-pass section by temporarily throttling the outlet of the air by-pass section to create jet-pump action. The second is to increase temporarily the resistance to flow or to disconnect the pump means temporarily in order to reduce the flow in the air by-pass section which transiently induces a forward flow in the car by-pass section. The third is to transfer some of the linear momentum of an incoming car to the resident car or cars primarily by means of naturally entrapped air column and secondarily by impact through elastic bumpers. The fourth is to use an externally powered mechanism to push the resident cars forward a distance of one car length.

24 Claims, 10 Drawing Figures



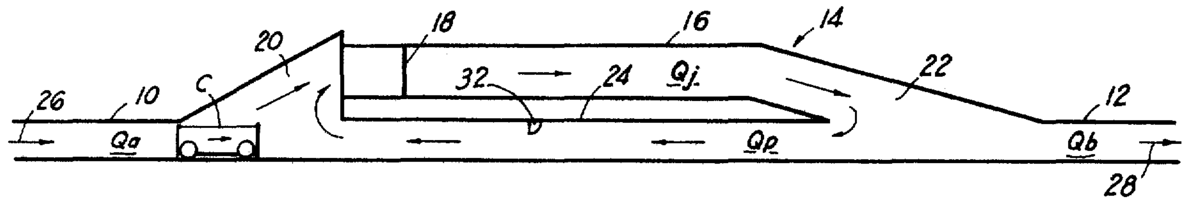


FIG 1

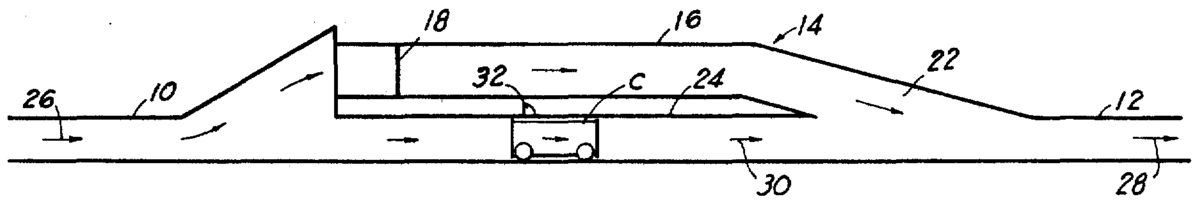


FIG 2

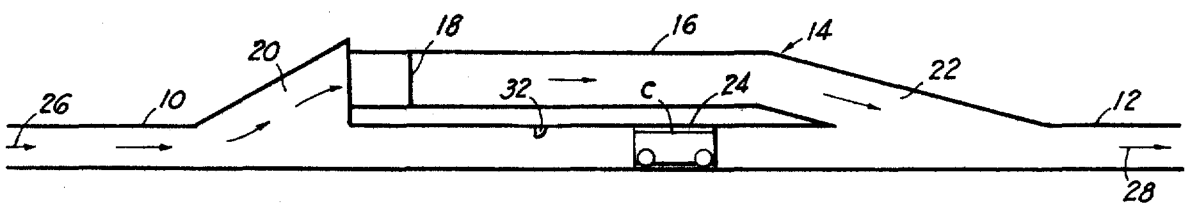


FIG 3

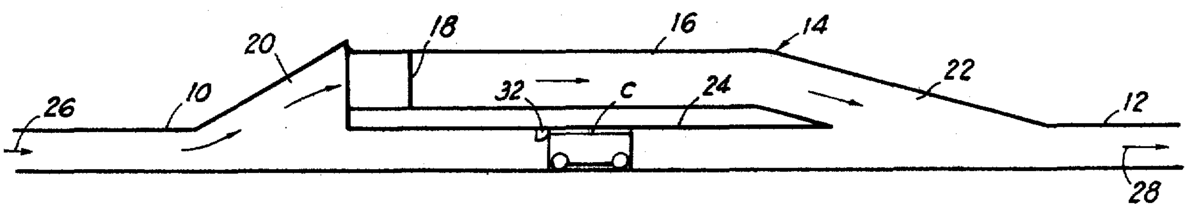


FIG 4

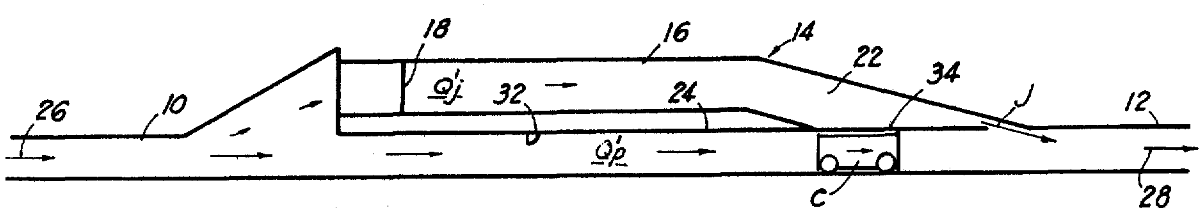


FIG 5

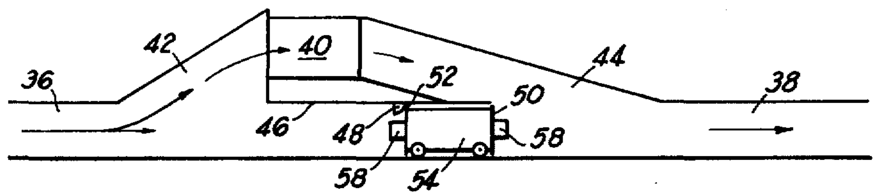


FIG 6

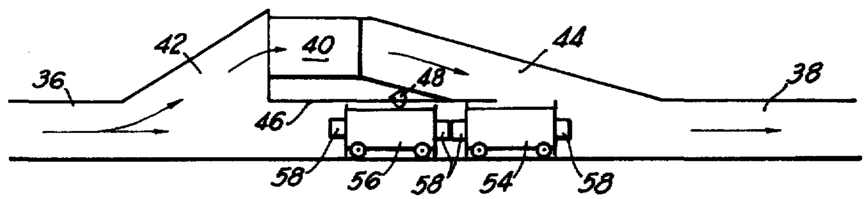


FIG 7

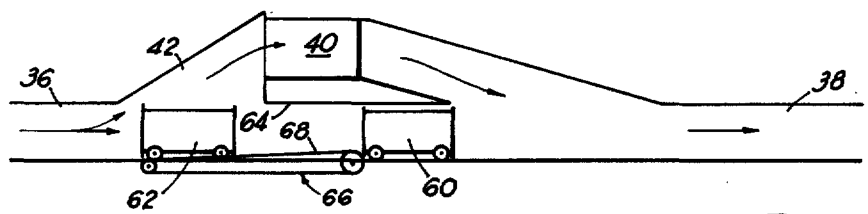


FIG 8

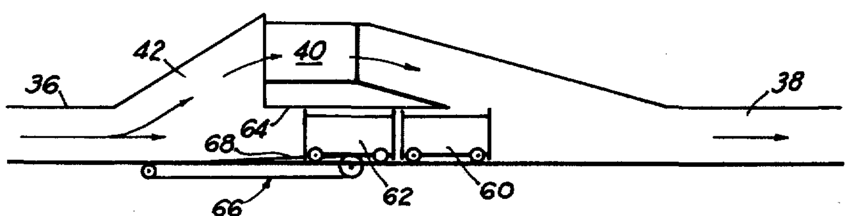


FIG 9

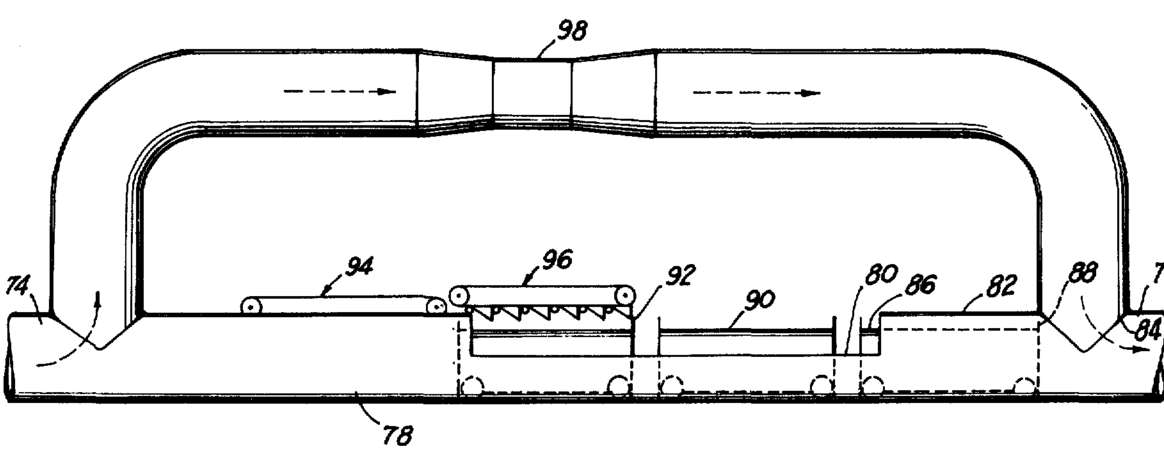


FIG 10

PUMP FOR USE IN A CAPSULE TRANSPORT PIPELINE

BACKGROUND OF THE INVENTION

This invention relates to modification of the cargo or other load transporting systems described in parent application Ser. No. 856,566, filed Sept. 10, 1969, now abandoned, and superseded by copending continuation-in-part application Ser. No. 140,071 filed May 3, 1971, now U.S. Pat. No. 3,797,405.

BRIEF SUMMARY OF THE INVENTION

This invention is directed to tube or conduit transport systems in which cars are swept along by air flowing freely within the system. The air flow is effected by pump means. In the aforesaid continuation-in-part application this air flow is effected by a series of booster pumps, each of which handles a fraction of the total air flow. Each booster pump withdraws a fraction of the system air and reintroduces it at a high velocity in the air flow direction so as to "boost" the system. With such booster pumps, they may achieve an efficiency of some 20–40 percent and it would be of advantage to obtain a higher value of efficiency in order to achieve a more economical system.

According to the present invention the pumps may operate at an efficiency of some 60–80 percent.

The system disclosed herein is characterized by the fact that each pump normally handles a mass rate flow of air which is somewhat greater than the mass rate flow of air flowing in the system. By having the pump outlet displaced downstream from the pump inlet with a car by-pass section paralleling the air flow through the pump between such inlet and outlet, a reverse flow of air normally tends to occur through the by-pass section. Thus, when a car reaches a by-pass section its forward progress is slowed and is tended to be reversed in the by-pass section. After a car has been stopped in a by-pass section (it may be held therein by positive means against the action of the reverse air flow) it may be reintroduced into the main stream flow beyond the pump outlet in several ways. A particularly advantageous method of doing so is to make the reintroduction dependent upon the arrival of a succeeding car at the same by-pass section. In this way, the progression of a series of cars through the system is inherently programmed and this technique is particularly advantageous when the cargo involved is some product such as coal, raw material, etc.

Another technique which may be employed to reintroduce a car into the main stream flow is by temporarily converting the pump associated with the by-pass section into a booster pump. Thus, by throttling the pump outlet, the air flow therethrough is reduced so that forward air flow tends to occur through the by-pass section and the car is expelled while the pump, now discharging a fraction of the system, air flow at much higher velocity, operates in booster pump fashion. After the car is expelled the pump is returned to normal operation by cessation of the throttling effect. This latter technique allows the cars to move through the system independently of succeeding car arrival as above.

The invention is particularly advantageous as an alternative for conveyor systems although it is not limited to such applications. By utilizing a system of appreciable length wherein a large number of the above pump stations are employed, however, the progress of cars

through the systems necessarily is slow as compared with a system in which, by the use of booster pumps, the cars are not constrained to stop at each pump station.

In one embodiment, cars one at a time enter the section and are braked to a stop by the reverse air flow tendency during which a loading or unloading operation could be performed and then are ejected from the section before the next car arrives. In this case, ejection is achieved by altering the air flow in such manner that the air tends to flow in forward direction through the by-pass section. This may be effected either by reducing the air flow through the pump means as by decreasing the power at the pump means or employing a controllable pitch blade or impeller pump, or the air flow through the pump means may be throttled. This embodiment also allows cars to pass through the by-pass section without being stopped.

In another embodiment, at least one car always remains in the by-pass section and the pump means is always effective to create the tendency for reverse air flow through the by-pass section. A succeeding car arriving at the by-pass section is then used to displace the lead car from the by-pass section once again to be swept along by the air flow. For rugged cargo, displacement may be effected simply by transferring the momentum of the succeeding car to the lead car and suitable bumpers may be used for this purpose. For more delicate cargo or in instances where the gross weight of various cars may differ significantly, means is provided first to intercept and slow down the succeeding car and then controllably to position or move it forwardly to a point at which it displaces or ejects the lead car from the by-pass section.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

FIGS. **1–5** illustrate sequential views of one embodiment of the invention;

FIG. **6** is a diagrammatic view showing a further embodiment of the invention;

FIG. **7** is a view similar to FIG. **6** but showing the manner in which a car is ejected from the station;

FIG. **8** is a view similar to FIG. **6** but showing a further modification of the invention;

FIG. **9** is a view similar to FIG. **8** but showing the manner of car ejection from the station;

FIG. **10** is a diagrammatic view illustrating certain principles of the belt mechanism associated with the embodiment of FIGS. **8** and **9**.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. **1**, entrance and exit sections of conduit means or pipeline are indicated respectively by the reference characters **10** and **12** and lead respectively to and from the station indicated generally by the reference character **14.** Air flow continuity between the sections **10** and **12** is maintained by the conduit section **16** having a full flow pump **18** located therein, the pump means having an inlet at **20** and an outlet at **22** so as to define, between the inlet and outlet, a car by-pass section **24** which is aligned with the two sections **10** and **12** and which permits a car such as that indicated by the reference character C free access through the system.

As disclosed in the aforementioned copending applications, the conduit means is of substantially uniform cross section and the car or cars C are of such cross sectional area as partially fills the cross section of the conduit means sufficiently to allow air flow as indicated by the arrows **26** and **28** to sweep the cars along for passage through the system. The sections **24** herein, however, are somewhat smaller than the sections **10** and **12** so that the cars can essentially block the flow of air therethrough. As disclosed in the copending applications, the cross sectional areas of the cars are such as to leave a continuous clearance space around the vehicles. In the embodiment shown, the quantity of fluid moving in the tube portion **10** upstream from the pumping station is represented by Q_a while the quantity of fluid flowing through the downstream portion **12** is represented by Q_b. The quantity of fluid flowing through the pump designated by Q_j is greater than the system air flow Q_a and the quantity of reverse flow of fluid as effected through the by-pass section **24** is represented by Q_p. Quantities Q_a and Q_b are equal so that Q_j is greater than either by the Value Q_p.

As the car C approaches and then enters the by-pass section **24** as shown in FIG. **2**, the reverse flow of air is blocked through the by-pass section **24** and, in fact, the momentum of the car will at least transiently effect forward direction movement of the air within the section **24** as indicated by the arrows **30**. With the car stopped as is shown in FIG. **3**, the by-pass section **24** is essentially blocked except for air which may leak past in reverse direction around the car and, at this time it will be apparent that a greater mass rate of air flows through the sections **10** and **12**, made essentially equal to Q_j. Since it is of interest to provide a quiescent air condition at the car and in the by-pass section in order to reduce fluid recirculation through **24** or during loading or unloading of the car, the by-pass section preferably is made of somewhat smaller cross section than the mainline sections **12**, **26** so that, in effect, the car substantially blocks or seals the by-pass section while in residence therein.

In FIG. **4**, the car C has been shown as having been backed up in the by-pass section **24** to engage against holding means such as a pawl-like stop **32** which was deflected out of the way as the car entered the section as shown in FIG. **2**, this backing up of the car being effected by virtue of the pressure differential in the section **24** created by the fluid flow pump in the air by-pass line **14** which is in communication with the section **24** at the inlet **20** and the outlet **22**. The car will remain in this position until ejected as is later described.

When it is desired to move the car from the section **24** and to eject the leading car back into the main stream of the conduit means, four methods may be employed.

The first method of ejection of the leading car is to change the flow pattern to induce a jet-pump action by moving a controllable shutter **34**, FIG. **5**, forward. By moving the shutter **34** forward, a jet stream J having a velocity greater than the main line air stream is injected into the main line in a direction nearly along the axis of the main line thereby inducing the afore-mentioned jet-pump action. The opening and closing of the controllable shutter **34** would be accomplished by an external mechanism. The external mechanism could be operated in a periodic manner or could be operated in response to a sensor signal that another car had entered the section **24**.

The second method of ejection of the leading car is to reduce the rate of flow Q_j through the air by-pass section **14** to a value less than the rate of flow in the main line, Q_a or Q_b, so that Q_p is in the forward direction in the section **24** by virtue of the law of conservation of mass. Reduction of Q_j can be achieved in a variety of ways such as temporarily closing a valve or temporarily disconnecting the pump rotor from the drive motor in the air by-pass section **14**. This, the second, method of injection is dependent upon the main line flow, Q_a or Q_b, being maintained by other booster pumps in the system during the time Q_j is reduced to eject a car from the section **24**.

The third method of ejection of the leading car is to transfer some of the linear momentum of the arriving car to the stationary car as shown in FIGS. **6** and **7**. In FIG. **6**, the upstream section is indicated by the reference character **36** and the downstream section of the conduit means is indicated by the reference character **38** and the pump **40** defines between its inlet **42** and its outlet **44** the car by-pass section **46** and the pump means is operated in such fashion as continually tends to create a reverse flow of fluid through the by-pass section **46**. However, in the system of FIGS. **6** and **7**, at least one car is always present in the by-pass section **46** so that it operates continually as a valve essentially blocking the reverse flow of air through the section **46**, the car being held in the section **46** against holding means such as a pawl-like means **48** by virtue of the positive pressure acting against the leading end of the car. In order to effect more completely a blocking action of the air flowing in reverse direction through the section **46** and to impart a more effectively smooth and shockless start for the lead car due to pressure forces developed in the fluid cushion trapped between the lead and trailing cars, the end plate or plates **50**, **52** may be essentially of the same cross sectional area as the section **46** which, under these circumstances, would be somewhat smaller in cross section than the sections **36** and **38**. In any event, the car designated by the reference character **54** in FIG. **6** will remain in the position shown until, as is shown in FIG. **7**, a following or succeeding car **56** enters the by-pass section **46** to build the aforesaid cushion and ultimately to collide with the leading car with greater or lesser impact dependent upon the forces exerted by the cushion. The momentum of the following car **56** is effective to displace the car **54** back into the main stream so that it passes through the section **38** and on to the next station. Suitable bumpers such as those indicated by reference characters **58** may be employed to cushion the shock created by collision of the vehicles.

The fourth method of ejection of the leading car is to employ an externally powered mechanism to push the stationary cars forward by one car length. In FIGS. **8** and **9** the forward push required to eject a car is provided by a conveyor-belt mechanism **66**. The gently sloping upper flight **68** of **66** allows the cars to straddle **68**, to slide onto **68**, and to become partially or totally supported on **68** in order that the car will be carried forward whenever the conveyor-belt mechanism **66** is in motion in a clockwise direction in FIGS. **8** and **9**. The conveyor-belt mechanism **66** may be operated continuously so that the leading car **60** is ejected shortly after a car arrives in the car by-pass section **64** or may be operated intermittently so that a car is ejected periodically. In FIG. **10** the forward push required to eject the leading car **86** is provided by a ratchet-drive mechanism **96.** Because the vehicles are stopped and do remain stationary for short periods of time before being ejected, the booster pump can also be used as a loading or unloading station, FIG. **10.** In FIG. **10** wherein it will be seen that the car by-pass section **78** is provided with a cutout or opening **80** intermediate its ends. The portion **82** of the by-pass section immediately preceding the pump outlet **84** is closed circumferentially so that the lead car **86** and more especially its leading end plate **88** forms effectively a valve blocking reverse flow of air or leakage past the lead car. An intermediate car **90** in residence is shown and a succeeding car **92** is shown in position for being disposed in the loading/unloading position and whereby the lead car **86** will be ejected or displaced from the by-pass section and back into the main stream of the conduit system. A slowly moving belt device **94** is employed at the upstream end of the by-pass section **78** frictionally to engage the upper portions of an entering car and to slow it down so that the car **92,** for example, is barely moving by the time it reaches the position shown beneath the mechanism **96.** The ratchet drive mechanism indicated generally by the reference character **96** is intermittently operated effectively to produce the displacement of the lead car from the system since a car entering the by-pass section will be slowed down by the belt device **94** and will, upon reaching the position of the car **92,** be at or substantially at a stopped condition until later propelled forwardly by the mechanism **96.**

In a system such as is described in conjunction with FIGS. **1–5** some loss of efficiency can be expected because the recirculation or reverse flow (FIG. **1**) itself represents waste energy insofar as movement of air within the system is concerned and, as described above, in the first and second methods of ejection a transient condition occurs during ejection of the lead car which is less efficient than full-flow pumping which takes place under the conditions of FIGS. **1–4.**

The first and second methods of ejection, FIGS. **1–5** however, does have the advantage of allowing the cars to progress through the system more or less independently or without programming.

The third method of ejection, FIGS. **6** and **7,** is characterized by its extreme simplicity inasmuch as no mechanism is required either to stop the cars or to reintroduce them downstream of the by-pass section. This simplicity of course is obtained at the expense of some loss in the independency of car progress (i.e. reintroduction of a leading car depends upon arrival of a succeeding car). Also, the system of FIGS. **6** and **7** is not well adapted to a system in which a large disparity in car weights is experienced.

The fourth method of ejection, FIGS. **8** and **9** (also the system of FIG. **10**) while requiring the additional complexity of the car slowing and lead car reintroduction means **66,** does relieve the system of any constraint imposed by unequal car weights.

In terms of pumping efficiency, the systems of FIGS. **6** and **7**; FIGS. **8** and **9**; and FIG. **10** are the most efficient since in each the various pumps in the system operate continually to handle the full flow of system air. It will be appreciated, however, that any system may employ various combinations of the above and, in fact, other booster pumps each handling only a part of the system air flow and operating on the jet principle as disclosed in copending application Ser. No. 140,071 and its parent application Ser. No. 856,566, usefully may be employed in any system otherwise constructed in accord with this invention.

It will also be understood that the present invention, like the disclosures of the above copending and parent applications, relates to a system for transporting vehicles wherein a high mass rate flow stream of air continuously flows in the system by reason of the fact that the cars are of smaller cross section than the tube so that as they move through the system they allow the air to sweep past them irrespective of the fact that the cars for short periods of time can be moving relatively slowly with respect to the velocity of the air stream. The cars are unstreamlined so that they present a high coefficient of drag and will be swept along by the moving air stream rapidly attaining a velocity approaching that of the air stream.

What is claimed is:

1. In a mass transportation system including a series of cars, conduit means for guiding said cars along a selected path and means for flowing air at a selected rate through said conduit means, the improvement wherein said means for flowing air includes pump means having an inlet for withdrawing air at one point from said conduit means and having an outlet for injecting air at another point into said conduit means, said points being spaced apart along the direction of air flow to define a car by-pass section, and means for causing said pump means to withdraw and inject air at a rate at least normally at a rate greater than said selected rate whereby to create a tendency for reverse air flow through said car by-pass section; and

holding means in opposition to said tendency for reverse air flow for causing at least one car of said series at a time to reside temporarily within said car by-pass section.

2. In a mass transportation system as defined in claim **1** including a throttle device selectively controlling the cross section of said outlet to cause said pump means temporarily to pump at a rate less than said selected rate.

3. In a mass transportation system as defined in claim **1** wherein said pump means is continuously operated to create said tendency for reverse air flow through the car by-pass section whereby the cars of the entire series arrive sequentially and reside temporarily at said by-pass section.

4. A mass transportation system as defined in claim **1** including means for arresting a car in transit at each by-pass section and for displacing a preceding car into exiting transit condition.

5. A mass transportation system as defined in claim **4** wherein the last means comprises a conveyor flight device for intercepting and controllably positioning a car in transit at the associated by-pass section.

6. In a mass transportation system as defined in claim **1** wherein said means for causing said pump means to withdraw and inject air comprises,

means for flowing more or less air through the pump means than that flowing through the conduit means.

7. In a mass transportation system as defined in claim **1** wherein the loading/unloading section includes a conduit open to the atmosphere and spaced upstream from the pump outlet.

8. A mass transportation system as defined in claim **1** comprising means for displacing a car from the loading/unloading section and to a position adjacent the pump outlet for ejecting the preceding car adjacent the pump outlet into and through the flowing air.

9. A mass transportation system comprising, in combination:

conduit means for defining a closed path of substantially uniform cross section;

a series of cars, each having a shape presenting a high coefficient of drag with respect to and flowing therepast and each of maximum cross section less than that of said conduit means to allow air to flow past the cars as they are moving along said path.

at least two pump means located at spaced points along said path for circulating air within said conduit means at velocity sufficient to sweep said cars along said path, each pump means having an inlet for withdrawing air at one point from said conduit means and having an outlet for injecting air at another point into said conduit means, each outlet being spaced from the associated inlet along the direction of air flow to define a car by-pass section, and means for operating each pump means to pump a mass rate of air greater than that flowing in the system so as normally to create a tendency for reverse air flow through each by-pass section;

holding means in each by-pass section for temporarily holding a car of said series in the by-pass section in opposition to reverse air flow tendency therethrough whereby car passage through said conduit means is always obstructed by at least one car in each by-pass section; and

said series of cars being of a number to provide at least one car always in transit between said by-pass sections to displace a preceding car from a by-pass section in which it is temporarily held.

10. A mass transportation system as defined in claim **9** including means for arresting a car in transit at each by-pass section and for displacing a preceding car into exiting transit condition.

11. A mass transportation system as defined in claim **10** wherein the last means comprises a conveyor flight device for intercepting and controllably positioning a car in transit at the associated by-pass section.

12. In a mass transportation system including a series of cars each having a shape presenting a high coefficient of drag with respect to air flowing past them and each presenting a selected maximum cross sectional area, conduit means having a substantially uniform cross sectional area greater than said selected cross sectional area, and means for flowing air at a high mass rate of flow through said conduit means whereby to sweep said cars through such conduit means, the improvement wherein:

said means for flowing air includes pump means having an inlet for withdrawing air at one point from said conduit means and having an outlet for injecting air at another point into said conduit means, said points being spaced apart along the direction of air flow to define a car by-pass section between them, and means for causing said pump means to withdraw and inject air at a rate sufficient to create a tendency for reverse air flow through said car by-pass section; and

holding means in opposition to said tendency for reverse air flow for causing at least one car of said series at a time to reside temporarily within said car by-pass section.

13. In a mass transportation system as defined in claim **12** wherein said means for causing said pump means to withdraw and inject air comprises a throttle device selectively controlling the cross section of said outlet.

14. A mass transportation system as defined in claim **13** including means for moving a car out of said other branch for further progress through the system.

15. In a mass transportation system as defined in claim **12** wherein said pump means is continuously operated to create said tendency for reverse air flow through the car by-pass section whereby the cars of the entire series arrive sequentially and reside temporarily at said by-pass section.

16. A mass transportation system as defined in claim **15** including means for arresting a car in transit at each by-pass section and for displacing a preceding car into exiting transit condition.

17. A mass transportation system as defined in claim **12** including means for arresting a car in transit at each by-pass section and for displacing a preceding car into exiting transit condition.

18. A mass transportation system as defined in claim **17** wherein the last means comprises a conveyor flight device for intercepting and controllably positioning a car in transit at the associated by-pass section.

19. In a mass transportation system as defined in claim **12** wherein said means for causing said pump means to withdraw and inject air comprises,

variable means for flowing more or less air through the pump means than flowing through the conduit means.

20. A mass transportation system as defined in claim **12** comprising means for displacing a car from the by-pass section and to a position adjacent the pump outlet for ejecting the preceding car adjacent the pump outlet into and through the flowing air.

21. A mass transportation system comprising, in combination:

conduit means for defining a closed path of substantially uniform cross section;

a series of cars each having a shape presenting a high coefficient of drag with respect to air flowing therepast and each of maximum cross section less than that of said conduit means to allow air to flow past the cars as they are moving along said path;

at least two pump means located at spaced points along said path for circulating air within said conduit means at velocity sufficient to sweep said cars along said path, each pump means having an inlet for withdrawing air at one point from said conduit means and having an outlet for injecting air at another point into said conduit means, each outlet being spaced from the associated inlet along the direction of air flow to define a car by-pass section, and means for operating each pump means so as to create a tendency for reverse air flow through each by-pass section;

holding means in each by-pass section for temporarily holding a car of said series in the by-pass section in opposition to reverse air flow tendency therethrough whereby car passage through said conduit means is always obstructed by at least one car in each by-pass section; and said series of cars being of a number to provide at least one car always in transit between said by-pass sections to displace a preceding car from a by-pass section in which it is temporarily held.

22. A mass transportation system as defined in claim **21** wherein the last means comprises a conveyor flight device for intercepting and controllably positioning a car in transit at the associated by-pass section.

23. A mass transportation system comprising, in combination:

transport tube means for conveying a stream of air and a succession of unstreamlined cars which are swept along by the stream of air; and

pump means located along said transport tube means for producing said stream of air;

said transport tube means including a branch point and a reentry point between which there is defined a car by-pass section and an air stream by-pass section in parallel;

said pump means including an air moving means in said air stream by-pass section for conveying air therethrough at a mass flow rate which tends to produce a reverse flow of air in said car by-pass section.

24. A mass transportation system comprising, in combination:

transport tube means for conveying a stream of air at a high mass rate of flow and a succession of unstreamlined cars swept along by said stream of air;

a plurality of pump means operatively associated with said transport tube means along the length thereof for producing and maintaining said stream of air therein at said high mass rate of flow;

said transport tube means having parallel branches at one region thereof through which the air stream and the cars respectively are conveyed; and

one of said pump means being located in that branch which conveys the air stream, said one pump means being operated at a capacity to handle a quantity of air greater than said air stream whereby to create a tendency for reverse air flow through the other branch which conveys the cars; and

said other branch including means for retaining a car therein in opposition to said tendency for reverse air flow whereby to allow an unloading or a loading operation to be performed thereon.

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